Innovation, Sciences et Développement économique Canada
Office de la Propriété Intellectuelle du Canada

Innovation, Science and Economic Development Canada
Canadian Intellectual Property Office

CA 3094679 C 2023/08/08

(11)(21) **3 094 679**

(12) **BREVET CANADIEN**
CANADIAN PATENT

(13) **C**

(22) Date de dépôt/Filing Date: 2020/09/29
(41) Mise à la disp. pub./Open to Public Insp.: 2021/04/04
(45) Date de délivrance/Issue Date: 2023/08/08
(30) Priorités/Priorities: 2019/10/04 (IN201941040204); 2019/11/26 (US16/696,025)

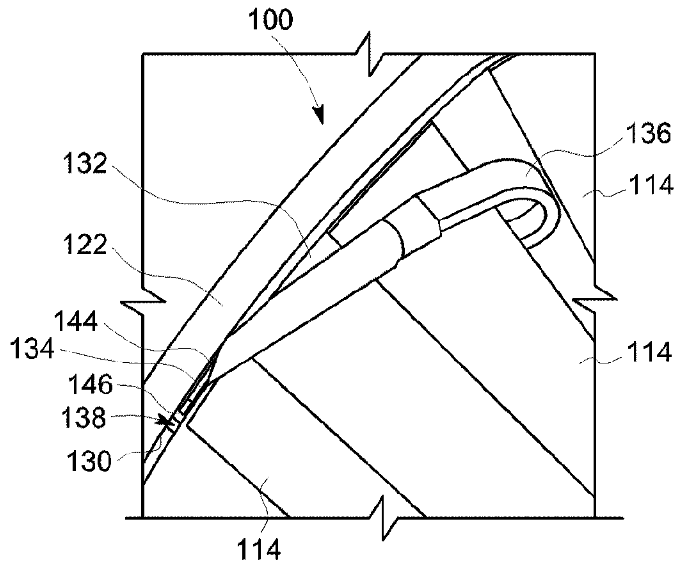
(51) Cl.Int./Int.Cl. *G01M 99/00* (2011.01), *F01D 25/00* (2006.01), *F02C 7/00* (2006.01)

(72) Inventeurs/Inventors:
TRIVEDI, DEEPAK, US;
BENNETT, GROVER ANDREW JR., US;
MEETHAL, MANOJ KUMAR KOYITHITTA, US;
SHADDOCK, DAVID MULFORD, US;
GRAHAM, ANDREW CRISPIN, US;
LECLERC, STEPHAN PAUL JR., US;
KUMAR, SANDEEP, US

(73) Propriétaire/Owner:
GENERAL ELECTRIC COMPANY, US

(74) Agent: BERESKIN & PARR LLP/S.E.N.C.R.L.,S.R.L.

(54) Titre : APPAREIL D`INSERTION A L`UTILISATION AVEC DES MACHINES ROTATIVES
(54) Title: INSERTION APPARATUS FOR USE WITH ROTARY MACHINES



(57) Abrégé/Abstract:
An insertion apparatus for use with a rotary machine includes a body extending from an insertion end to a steering end and sized to fit within an annular cavity. The body has a first stiffness and curves along a circumference of the annular cavity as the insertion end travels through the annular cavity. The insertion apparatus also includes a stiffener coupled to the body and extending from the steering end to the insertion end. The stiffener has a second stiffness greater than the first stiffness. The insertion apparatus further includes at least one maintenance device coupled to the insertion end of the insertion apparatus and a displacement mechanism configured to adjust a position of the at least one maintenance device relative to the body.

ABSTRACT

An insertion apparatus for use with a rotary machine includes a body extending from an insertion end to a steering end and sized to fit within an annular cavity. The body has a first stiffness and curves along a circumference of the annular cavity as the insertion end travels through the annular cavity. The insertion apparatus also includes a stiffener coupled to the body and extending from the steering end to the insertion end. The stiffener has a second stiffness greater than the first stiffness. The insertion apparatus further includes at least one maintenance device coupled to the insertion end of the insertion apparatus and a displacement mechanism configured to adjust a position of the at least one maintenance device relative to the body.

Date Reçue/Date Received 2020-09-29

INSERTION APPARATUS FOR USE WITH ROTARY MACHINES

[0001] Intentionally left blank

BACKGROUND

[0002] The field of the disclosure relates generally to an insertion apparatus and, more particularly, to an insertion apparatus for use with rotary machines having annular cavities.

[0003] At least some known rotary machines, such as turbines for aircraft engines and gas and steam powered turbines for industrial applications, include an outer case and at least one rotor that carries multiple stages of rotating airfoils, i.e., blades, which rotate with respect to the outer case. In addition, the outer case carries multiple stages of stationary airfoils, i.e., guide vanes. The blades and guide vanes are arranged in alternating stages. In at least some known rotary machines, shrouds are disposed on the radially inner surfaces of a stator to form a ring seal around tips of the blades.

[0004] At least some rotary machines are inspected periodically to determine if components of the rotary machines need repair and/or replacement. However, some components of the rotary machine may be difficult to access and inspect without disassembly of the rotary machine. For example, some components, such as clips attaching the shrouds to shroud hangers, are positioned in annular cavities extending circumferentially around the shrouds. However, the size, shape, and location of the annular cavities prevent at least some known inspection apparatus from accessing and inspecting the clips. Moreover, the annular cavities may be obstructed by components, such as the clips, that extend at least partially into the annular cavities.

[0005] Accordingly, it is desirable to provide an insertion apparatus for use with a rotary machine that is configured to inspect components positioned along an annular cavity of the rotary machine.

BRIEF DESCRIPTION

[0006] In one aspect, an insertion apparatus for use with a rotary machine is provided. The rotary machine defines an annular cavity extending along a circumference. The insertion apparatus includes an insertion end positionable within the annular cavity and configured to travel through the annular cavity. The insertion apparatus also includes a steering end opposite the insertion end. The insertion apparatus further includes a body extending from the insertion end to the steering end and sized to fit within the annular cavity. The body has a first stiffness and curves along the circumference as the insertion end travels through the annular cavity. The insertion apparatus also includes a stiffener coupled to the body and extending from the steering end to the insertion end. The stiffener has a second stiffness greater than the first stiffness. The insertion apparatus further includes at least one maintenance device coupled to the insertion end of the insertion apparatus and a displacement mechanism configured to adjust a position of the at least one maintenance device relative to the body.

[0007] In another aspect, a system for use with a rotary machine is provided. The rotary machine defines an annular cavity extending along a circumference. The system includes an insertion apparatus including a body extending from an insertion end to a steering end. The body is sized to fit within the annular cavity and is curves along the circumference. The system also includes at least one maintenance device coupled to the insertion end of the insertion apparatus and a displacement mechanism configured to adjust a position of the at least one maintenance device relative to the body. The system further includes a guide tube positionable in a port of the rotary machine and configured to define a path for the insertion apparatus into the annular cavity. The guide tube is curved to form an at least partially helical path around objects and is sized to extend adjacent an opening into the annular cavity.

Date Reçue/Date Received 2020-09-29

[0008] In yet another aspect, a method of inspecting a rotary machine is provided. The rotary machine defines an annular cavity extending along a circumference. The method includes positioning a guide tube in a port of the rotary machine to define a path for an insertion apparatus into the annular cavity. The guide tube is curved to form an at least partially helical shape. The method also includes positioning the insertion apparatus along the path and into the annular cavity. The insertion apparatus includes a body having an insertion end and a steering end opposite the insertion end. The body is sized to fit within the annular cavity and is curves along the circumference. The method further includes directing the insertion end of the insertion apparatus through the annular cavity. At least one maintenance device is coupled to the insertion end of the insertion apparatus. The method also includes positioning the at least one maintenance device adjacent a portion of the rotary machine using a displacement mechanism configured to adjust a position of the at least one maintenance device relative to the body.

DRAWINGS

[0009] These and other features, aspects, and advantages of the present disclosure will become better understood when the following detailed description is read with reference to the accompanying drawings in which like characters represent like parts throughout the drawings, wherein:

[0010] FIG. 1 is a cross-sectional schematic view of an exemplary rotary machine;

[0011] FIG. 2 is a schematic view of a system including an insertion apparatus and a guide tube positioned within a primary cavity of the rotary machine shown in FIG. 1;

[0012] FIG. 3 is a schematic view of the insertion apparatus shown in FIG. 2 traveling along the annular cavity of the rotary machine shown in FIG. 1;

[0013] FIG. 4 is a side view of a portion of the insertion apparatus shown in FIGS. 2 and 3;

[0014] FIG. 5 is a perspective view of the guide tube shown in FIG. 2;

Date Reçue/Date Received 2020-09-29

[0015] FIG. 6 is a perspective view of an alternative embodiment of a displacement mechanism for use with the insertion apparatus shown in FIGS. 2-4; and

[0016] FIG. 7 is a flow chart of an exemplary method of inspecting a rotary machine.

[0017] Unless otherwise indicated, the drawings provided herein are meant to illustrate features of embodiments of this disclosure. These features are believed to be applicable in a wide variety of systems comprising one or more embodiments of this disclosure. As such, the drawings are not meant to include all conventional features known by those of ordinary skill in the art to be required for the practice of the embodiments disclosed herein.

DETAILED DESCRIPTION

[0018] In the following specification and the claims, reference will be made to a number of terms, which shall be defined to have the following meanings.

[0019] The singular forms “a”, “an”, and “the” include plural references unless the context clearly dictates otherwise.

[0020] “Optional” or “optionally” means that the subsequently described event or circumstance may or may not occur, and that the description includes instances where the event occurs and instances where it does not.

[0021] Approximating language, as used herein throughout the specification and claims, may be applied to modify any quantitative representation that could permissibly vary without resulting in a change in the basic function to which it is related. Accordingly, a value modified by a term or terms, such as “about”, “approximately”, and “substantially”, are not to be limited to the precise value specified. In at least some instances, the approximating language may correspond to the precision of an instrument for measuring the value. Here and throughout the specification and claims, range limitations may be combined and/or interchanged, such ranges are identified and include all the sub-ranges contained therein unless context or language indicates otherwise.

Date Reçue/Date Received 2020-09-29

[0022] Embodiments described herein provide a system for use with a rotary machine having an annular cavity. The system includes an insertion apparatus configured to position a maintenance device along the annular cavity of the rotary machine. In addition, in some embodiments, the system includes a guide tube positionable in a port of the rotary machine and configured to guide the insertion apparatus into the annular cavity. For example, the guide tube is curved and has a helical shape. During deployment, the insertion apparatus is inserted along a path defined by the guide tube into the annular cavity and directed along the annular cavity. The insertion apparatus is sized and shaped to fit within and move along the annular cavity. The maintenance device is coupled to an insertion end of the insertion apparatus and is positionable relative to the rotary machine using a displacement mechanism. As a result, the system allows inspection and/or repair of components at locations within the annular cavity of the rotary machine.

[0023] FIG. 1 is a cross-sectional schematic view of an exemplary rotary machine. In the exemplary embodiment, the rotary machine includes a turbine assembly 100. In alternative embodiments, the rotary machine includes any assembly. For example, in some embodiments, the rotary machine includes, without limitation, any of the following: a compressor, a blower, a pump, a turbine, a motor, and a generator.

[0024] In the exemplary embodiment, turbine assembly 100 includes an inlet 102, a compressor 104, a combustor 106, a turbine 108, an outer case 110, and an exhaust 112. Fluid flows from inlet 102, through compressor 104, through combustor 106, through turbine 108 and is discharged through exhaust 112. Also, in the exemplary embodiment, compressor 104 and turbine 108 include airfoils configured to direct fluid through turbine assembly 100. In particular, compressor 104 and turbine 108 include blades 114, 116 and guide vanes 118, 120. Together, blades 114, 116, guide vanes 118, 120, and shrouds 122 (shown in FIG. 2) define a primary flowpath 124 of turbine assembly 100. This flowpath, combined with a flowpath through combustor 106, defines a primary cavity within turbine assembly 100. In alternative embodiments, turbine assembly 100 is configured in any manner that enables turbine assembly 100 to operate as described herein.

Date Reçue/Date Received 2020-09-29

[0025] Blades 114, 116 are operably coupled with rotating shafts 126, 128 such that blades 114, 116 rotate when rotating shafts 126, 128 rotate. Accordingly, blades 114, 116 and rotating shafts 126, 128 form a rotor of turbine assembly 100. Guide vanes 118, 120 and shrouds 122 are stationary components and are coupled to an interior surface 130 of outer case 110. Blades 114, 116 and guide vanes 118, 120 are generally positioned alternatingly along the rotor axis within turbine assembly 100. In alternative embodiments, compressor 104 and/or turbine 108 includes any airfoils that enable turbine assembly 100 to operate as described herein.

[0026] FIG. 2 is a schematic view of a system 132 including an insertion apparatus 134 and a guide tube 136 positioned in the primary cavity of turbine assembly 100. FIG. 3 is a schematic view of insertion apparatus 134 traveling along an annular cavity 138 of turbine assembly 100. Annular cavity 138 extends along a circumference of a respective shroud 122 of turbine assembly 100.

[0027] In the exemplary embodiment, shrouds 122 are at least partially supported by a hanger and extend circumferentially around blades 114, 116 and alongside a turbine central frame 140. Clips 142 couple shrouds 122 to hangers and secure shrouds 122 in position during operation of turbine assembly 100. In the exemplary embodiment, clips 142 are C-shaped and extend at least partially into annular cavity 138. Clips 142 are spaced apart along the circumference of each shroud 122. Accordingly, clips 142 are difficult to access from the exterior of turbine assembly 100 or from the primary cavity of turbine assembly 100. Insertion apparatus 134 is sized and shaped to fit within annular cavity 138 and facilitates inspection and/or repair at locations within annular cavity 138 that are difficult to access from an exterior of turbine assembly 100 by conventional means, such as using a borescope tool. Specifically, in contrast to at least some known insertion apparatus, insertion apparatus 134 is configured to extend into annular cavity 138 to facilitate inspection of clips 142.

[0028] During operation, insertion apparatus 134 enters turbine assembly 100 through any suitable access port or opening of turbine assembly 100. For example, in some

Date Reçue/Date Received 2020-09-29

embodiments, insertion apparatus 134 enters and/or exits turbine assembly 100 through any of inlet 102 (shown in FIG. 1), exhaust 112 (shown in FIG. 1), and/or an access port, such as an igniter, borescope, or fuel nozzle port. In the exemplary embodiment, insertion apparatus 134 is sized and shaped to fit within turbine assembly 100 and to travel along annular cavity 138. For example, insertion apparatus 134 has a height, length, and width that are less than a clearance required to fit within annular cavity 138. In alternative embodiments, insertion apparatus 134 is any size and shape that enables insertion apparatus 134 to operate as described herein.

[0029] Also, in the exemplary embodiment, guide tube 136 extends through a port of turbine assembly 100 and defines a path for insertion apparatus 134. For example, guide tube 136 defines an interior space sized to receive insertion apparatus 134 and allow insertion apparatus 134 to travel through guide tube 136. Guide tube 136 may be fixed to turbine assembly 100 by a flange (not shown) coupled to a port of turbine assembly 100. For example, in some embodiments, a flange extends around guide tube 136 and is sized to fit onto a port of turbine assembly 100. In alternative embodiments, guide tube 136 is coupled to turbine assembly 100 in any manner that enables guide tube 136 to operate as described herein.

[0030] In addition, in the exemplary embodiment, guide tube 136 is configured to direct insertion apparatus 134 into annular cavity 138 of turbine assembly 100. For example, guide tube 136 is curved and defines a curved path for insertion apparatus 134. Specifically, guide tube 136 is curved in three-dimensions and has a helical shape. Accordingly, guide tube 136 is able to guide insertion apparatus 134 around obstacles in the primary cavity of turbine assembly 100. In addition, guide tube 136 is sized such that a tip 144 of guide tube 136 is positioned proximate a target area within turbine assembly 100, e.g., an opening into annular cavity 138. In alternative embodiments, guide tube 136 is any size and shape that enables guide tube 136 to operate as described herein.

[0031] During operation, insertion apparatus 134 is used to inspect and/or repair any interior components of turbine assembly 100. For example, in some embodiments,

Date Reçue/Date Received 2020-09-29

insertion apparatus 134 is positioned adjacent a portion of interior surface 130 of turbine assembly 100 within annular cavity 138. Interior surface 130 may include a surface of clips 142. In some embodiments, insertion apparatus 134 detects a characteristic of interior surface 130. For example, in some embodiments, insertion apparatus 134 is used to generate an image of interior surface 130 and the image is examined to determine the condition of turbine assembly 100 and assess whether repairs are necessary. In further embodiments, insertion apparatus 134 includes a sensor that detects characteristics of interior surface 130. If repairs are necessary, in some embodiments, insertion apparatus 134 is used to repair interior surface 130. After inspection and/or repair of interior surface 130, insertion apparatus 134 exits turbine assembly 100 through any suitable access port or opening of turbine assembly 100, such as via the route of entry.

[0032] FIG. 4 is a side view of a portion of insertion apparatus 134. Insertion apparatus 134 includes an insertion end 146 and a steering end 148 opposite insertion end 146. Insertion end 146 is positionable within annular cavity 138 (shown in FIG. 3) of turbine assembly 100 (shown in FIG. 1) at target locations, such as adjacent clips 142 (shown in FIG. 3). In some embodiments, insertion end 146 is shaped to facilitate movement of insertion apparatus 134 through annular cavity 138 (shown in FIG. 3) without insertion apparatus 134 being caught on objects. For example, in some embodiments, insertion end 146 is curved. In further embodiments, insertion end 146 is angled, e.g., insertion end 146 has a V-shape.

[0033] Also, in the exemplary embodiment, insertion apparatus 134 includes at least one maintenance device 150 coupled to insertion end 146 of insertion apparatus 134 to allow insertion apparatus 134 to perform an inspection and/or repair operation within annular cavity 138 (shown in FIG. 3) of turbine assembly 100 (shown in FIG. 1). In some embodiments, maintenance device 150 includes at least one sensor 152 that is configured to contact surfaces. For example, in some embodiments, sensor 152 is an eddy current sensor. In alternative embodiments, insertion apparatus 134 includes any maintenance device 150 that enables insertion apparatus 134 to operate as described herein. For

Date Reçue/Date Received 2020-09-29

example, in some embodiments, maintenance device 150 of insertion apparatus 134 includes, without limitation, any of the following: an applicator, a drill, a grinder, a heater, a welding electrode, a sprayer, an optical sensor (e.g., visible, infrared, and/or multi-spectral sensor), a mechanical sensor (e.g., stylus profilometer, coordinate measurement probe, load transducer, linear variable differential transformer), a thermal sensor (e.g., pyrometer, thermocouple, resistance temperature detector), a magnetic sensor, an acoustic sensor (e.g., piezoelectric, microphone, ultrasound), and an electromagnetic sensor (e.g., eddy current, potential drop, x-ray).

[0034] In addition, in the exemplary embodiment, maintenance device 150 is positionable in a plurality of orientations using a displacement mechanism 154. For example, in the exemplary embodiment, maintenance device 150 is pivotably coupled to insertion end 146 of insertion apparatus 134. Displacement mechanism 154 includes a cable 156 extending from maintenance device 150 to steering end 148. Maintenance device 150 is selectively pivoted by manipulating cable 156. For example, maintenance device 150 is positionable between a first orientation in which maintenance device 150 is aligned with a translation direction 158 of insertion apparatus 134 and a second orientation in which insertion apparatus 134 extends at an angle relative to translation direction 158. The ability to position maintenance device 150 in a plurality of orientations facilitates precise positioning of maintenance device 150 relative to a target location. In alternative embodiments, maintenance device 150 is positionable in any manner that enables insertion apparatus 134 to operate as described herein.

[0035] Also, in the exemplary embodiment, insertion apparatus 134 includes a body 160 extending from insertion end 146 to steering end 148. Body 160 is sized and shaped to fit within annular cavity 138 (shown in FIG. 3). For example, body 160 includes a first surface 162, a second surface 164 opposite first surface 162, and edges 166 extending along first surface 162 and second surface 164. First surface 162 and second surface 164 extend from steering end 148 to insertion end 146 and define a thickness 168 of body 160 therebetween. Thickness 168 is less than a width of each of first surface 162 and second surface 164. For

Date Reçue/Date Received 2020-09-29

example, in some embodiment, thickness 168 of body 160 is less than about 0.02 inches. In addition, first surface 162 and second surface 164 are substantially smooth, e.g., free of bumps, perforations, folds, or other surface features. Accordingly, body 160 is ribbon-shaped. In alternative embodiments, body 160 has any shape that enables insertion apparatus 134 to function as described herein.

[0036] Moreover, in the exemplary embodiment, body 160 is flexible and conforms to a curve of annular cavity 138. Specifically, body 160 has a first stiffness and is configured to curve in a direction perpendicular to first surface 162 and second surface 164 along the curve of annular cavity 138. Accordingly, insertion apparatus 134 is able to travel within annular cavity 138 circumferentially along shroud 122 (shown in FIG. 2). Also, body 160 has a length that is greater than a circumference of shroud 122 such that insertion apparatus 134 is configured to extend from the exterior of turbine assembly 100 (shown in FIG. 2), into annular cavity 138 (shown in FIG. 2) and through the entirety of annular cavity 138. In the exemplary embodiment, body 160 includes at least one conductor 170, e.g., a flexible metal wire, encased within insulation 172. In alternative embodiments, insertion apparatus 134 includes any body 160 that enables insertion apparatus 134 to operate as described herein.

[0037] In addition, in the exemplary embodiment, insertion apparatus 134 includes a stiffener 174 coupled to and extending along body 160 from steering end 148 to insertion end 146. In some embodiments, stiffener 174 is coupled to body 160 or formed integrally with body 160. Stiffener 174 is configured to resist bending of body 160 and facilitate translation and steering of insertion apparatus 134 within annular cavity 138 (shown in FIG. 3). Moreover, stiffener 174 prevents body 160 from folding as insertion apparatus 134 is moved. Stiffener 174 has a second stiffness greater than the first stiffness of body 160. For example, in some embodiments, stiffener 174 includes a material that has a greater stiffness per unit volume than the material of body 160. In further embodiments, stiffener 174 has a thickness greater than thickness 168 of body 160. In the exemplary embodiment, stiffener 174 includes at least one cable and/or at least one hollow tube extending from

Date Reçue/Date Received 2020-09-29

steering end 148 to insertion end 146. Stiffener 174 has a width that is less than a width of body 160 and allows some flexing of body 160. In alternative embodiments, insertion apparatus 134 includes any stiffener 174 that enables insertion apparatus 134 to operate as described herein. In further embodiments, stiffener 174 is omitted.

[0038] In some embodiments, body 160 and/or stiffener 174 is configured to convey power and communication signals for maintenance device 150. In further embodiments, maintenance device 150 transmits and receives signals and/or power using any wired and/or wireless connections. For example, in some embodiments, a component, such as a harness or tether, extends from maintenance device 150 to the exterior of turbine assembly 100 and provides power to maintenance device 150, allows maintenance device 150 to send and/or receive signals, and/or transmits mechanical force, fluids, or thermal energy to maintenance device 150.

[0039] FIG. 5 is a perspective view of guide tube 136. Guide tube 136 includes a body 176 and tip 144. Together body 176 and tip 144 define an interior cavity 178 sized to receive insertion apparatus 134 (shown in FIG. 4). Guide tube 136 is configured to guide insertion apparatus 134 (shown in FIG. 2) toward annular cavity 138 (shown in FIG. 2). Body 176 is substantially rigid relative to insertion apparatus 134 (shown in FIG. 2) such that body 176 does not deform when insertion apparatus 134 travels through guide tube 136. In addition, body 176 is curved in 3-dimensions and forms a helical shape. When positioned in a port of turbine assembly 100 (shown in FIG. 2), guide tube 136 defines a path for insertion apparatus 134 around components of turbine assembly 100, such as blades 114 (shown in FIG. 2), and into annular cavity 138 (shown in FIG. 2). In alternative embodiments, guide tube 136 includes any body 176 that enables guide tube 136 to function as described herein. For example, in some embodiments, body 176 is segmented and the segments of body 176 are positionable relative to each other.

[0040] Also, in the exemplary embodiment, tip 144 is pliable and has a stiffness less than the stiffness of body 176. In addition, tip (144) is relatively flexible compared to the rest of guide tube 136. Accordingly, tip 144 may deform when contacted by insertion apparatus

Date Reçue/Date Received 2020-09-29

134. Tip 144 facilitates guiding insertion apparatus 134 into the opening of annular cavity 138 when guide tube 136 is positioned proximate annular cavity 138. In alternative embodiments, guide tube 136 includes any tip that enables guide tube 136 to function as described herein.

[0041] FIG. 6 is a perspective view of an alternative embodiment of a displacement mechanism 200 for use with the insertion apparatus 134 (shown in FIGS. 2-4). Displacement mechanism 200 is configured to adjust the orientation of maintenance device 150 (shown in FIG. 4) relative to insertion end 146 (shown in FIG. 4) of insertion apparatus 134. For example, displacement mechanism 200 includes an inflatable bladder 202 and a flexible tube 204 configured to deliver a fluid to inflatable bladder 202. Inflatable bladder 202 is configured to couple to maintenance device 150 (shown in FIG. 4). In addition, inflatable bladder 202 is configured to switch between a deflated position and an at least partially inflated position to adjust the position of maintenance device 150 relative to body 160 (shown in FIG. 4) of insertion apparatus 134 (shown in FIG. 4).

[0042] Also, in the exemplary embodiment, flexible tube 204 extends from insertion end 146 (shown in FIG. 4) to steering end 148 (shown in FIG. 4) and is configured to carry fluid such as air, water, and/or any other suitable fluid to inflatable bladder 202. In some embodiments, displacement mechanism 200 includes a valve or other regulatory mechanism to allow control of the fluid flow through flexible tube 204. In some embodiments, flexible tube 204 provides stiffness to body 160 (shown in FIG. 4) and acts as stiffener 174 (shown in FIG. 4) of insertion apparatus 134 (shown in FIG. 4).

[0043] FIG. 7 is a flow chart of an exemplary method 300 of inspecting turbine assembly 100 (shown in FIG. 1). In reference to FIGS. 1-3 and 7, method 300 includes positioning 302 guide tube 136 in a port of the rotary machine to define a path for insertion apparatus 134 into annular cavity 138 defined by shroud 122. For example, in some embodiments, a flange fits onto a port of turbine assembly 100 and couples guide tube 136 to turbine assembly 100. Guide tube 136 defines a path from an exterior of turbine assembly 100, through the port, and into annular cavity 138. Guide tube 136 is shaped to curve around

Date Reçue/Date Received 2020-09-29

obstacles within turbine assembly 100 and is sized such that tip 144 of guide tube 136 is positioned adjacent an opening into annular cavity 138. In alternative embodiments, guide tube 136 defines any path that enables system 132 to operate as described herein.

[0044] In addition, method 300 includes positioning 304 insertion apparatus 134 along the path and into annular cavity 138. For example, in some embodiments, insertion apparatus 134 is inserted into the interior cavity 178 of guide tube 136 and moved through guide tube 136. Guide tube 136 guides insertion apparatus 134 around obstacles within turbine assembly 100 and into annular cavity 138 as insertion apparatus 134 is moved along the path defined by guide tube 136. In some embodiments, method 300 includes deforming tip 144 to guide insertion apparatus 134 into annular cavity 138. For example, in some embodiments, tip 144 has a stiffness less than the stiffness of body 176 and allows insertion apparatus 134 to transition smoothly from guide tube 136 and into annular cavity 138.

[0045] Also, method 300 includes directing 306 insertion end 146 of insertion apparatus 134 through annular cavity 138. For example, in some embodiments, insertion end 146 of insertion apparatus 134 is directed through annular cavity 138 using a steering interface located at steering end 148. In some embodiments, insertion end 146 is directed by moving body 160 along translation direction 158. Insertion end 146 moves along the circumference of shroud 122 within annular cavity 138 as body 160 is moved in translation direction 158. After insertion end 146 has traveled around substantially the entire circumference of shroud 122 or has passed a desired target location, insertion apparatus 134 may be moved backwards along translation direction 158 within annular cavity 138. In alternative embodiments, insertion apparatus 134 is moved in any manner that enables insertion apparatus 134 to operate as described herein.

[0046] Also, method 300 includes positioning 308 maintenance device 150 coupled to insertion end 146 of insertion apparatus 134 adjacent a portion of the rotary machine using displacement mechanism 154. For example, in some embodiments, cable 156 of displacement mechanism 154 is used to pivot maintenance device 150 about insertion end 146 of insertion apparatus 134 such that maintenance device 150 contacts interior surface

Date Reçue/Date Received 2020-09-29

130 of clips 142. In further embodiments, inflatable bladder 202 (shown in FIG. 6) is inflated/deflated to adjust the position of maintenance device 150.

[0047] Moreover, method 300 includes detecting 310 a characteristic of an interior portion of the rotary machine using maintenance device 150. For example, in some embodiments, maintenance device 150 includes sensor 152 with electrodes that contact clips 142 within annular cavity 138 to determine a characteristic of clips 142. Displacement mechanism 154 facilitates maintenance device 150 properly contacting clips 142 or other components of turbine assembly 100. Accordingly, insertion apparatus 134 is able to provide accurate and reliable information for components along annular cavity 138.

[0048] The above described embodiments provide a system for use with a rotary machine having an annular cavity. The system includes an insertion apparatus configured to position a maintenance device along the annular cavity of the rotary machine. In addition, in some embodiments, the system includes a guide tube positionable in a port of the rotary machine and configured to guide the insertion apparatus into the annular cavity. For example, the guide tube is curved and has a helical shape. During deployment, the insertion apparatus is inserted along a path defined by the guide tube into the annular cavity and directed along the annular cavity. The insertion apparatus is sized and shaped to fit within and move along the annular cavity. The maintenance device is coupled to an insertion end of the insertion apparatus and is positionable relative to the rotary machine using a displacement mechanism. As a result, the system allows inspection and/or repair of components at locations within the annular cavity of the rotary machine.

[0049] An exemplary technical effect of the methods, systems, and apparatus described herein includes at least one of: (a) reducing the time to inspect and/or repair a rotary device or other applicable circular mechanism; (b) increasing the accessibility of difficult-to-reach locations within a turbine assembly for inspection and/or in situ repair; (c) reducing the time that circular mechanisms are out of service for maintenance; (d) increasing the precision and/or reliability of inspection and repair of circular mechanisms; (e) reducing

Date Reçue/Date Received 2020-09-29

unplanned service outages for a circular mechanisms; (f) enhancing data capture for use in quantifying and/or modeling the service condition of at least some components of the circular mechanism; and (g) providing a system and method for inspecting shroud hanger clips within an annular cavity.

[0050] Exemplary embodiments of methods and systems for use with rotary machines are not limited to the specific embodiments described herein, but rather, components of systems and/or steps of the methods may be utilized independently and separately from other components and/or steps described herein. For example, the methods and systems may also be used in combination with other systems requiring inspection and/or repair of components, and are not limited to practice with only the systems and methods as described herein. Rather, the exemplary embodiment can be implemented and utilized in connection with many other applications, equipment, and systems that may benefit from using a service apparatus for inspection and/or repair.

[0051] Although specific features of various embodiments of the disclosure may be shown in some drawings and not in others, this is for convenience only. In accordance with the principles of the disclosure, any feature of a drawing may be referenced and/or claimed in combination with any feature of any other drawing.

WHAT IS CLAIMED IS:

1. An insertion apparatus for use with a rotary machine, the rotary machine defining an annular cavity extending along a circumference, said insertion apparatus comprising:

an insertion end positionable within the annular cavity and configured to travel through the annular cavity;

a steering end opposite said insertion end;

a body extending from said insertion end to said steering end and sized to fit within the annular cavity, wherein said body includes a first material having a first stiffness and curves along the circumference as said insertion end travels through the annular cavity;

a stiffener coupled to said body and extending from said steering end to said insertion end, wherein said stiffener includes a second material having a second stiffness greater than the first stiffness and is configured to resist bending of said body;

at least one maintenance device coupled to said insertion end of said insertion apparatus; and

a displacement mechanism configured to adjust a position of said at least one maintenance device relative to said body.

2. The insertion apparatus in accordance with Claim 1, wherein said body comprises a first surface and a second surface opposite said first surface, said first surface and said second surface extending from said steering end to said insertion end, said body having a thickness defined between said first surface and said second surface, wherein the thickness is less than a width of said first surface and said second surface, and wherein said body is configured to curve in a direction perpendicular to said first surface and said second surface.

3. The insertion apparatus in accordance with Claim 2, wherein the thickness of said body is less than 0.02 inches.

Date Reçue/Date Received 2023-01-27

4. The insertion apparatus in accordance with Claim 1, wherein said stiffener comprises at least one of a cable and a hollow tube.

5. The insertion apparatus in accordance with Claim 1, wherein said displacement mechanism includes an inflatable bladder and a flexible tube configured to deliver a fluid to said inflatable bladder, wherein said inflatable bladder is configured to switch between a deflated position and an at least partially inflated position to adjust the position of said at least one maintenance device relative to said body.

6. The insertion apparatus in accordance with Claim 1, wherein said at least one maintenance device is pivotably coupled to said insertion end, and wherein said displacement mechanism is configured to pivot said at least one maintenance device about said insertion end.

7. The insertion apparatus in accordance with Claim 1, wherein said body is configured to convey power and communication signals for said at least one maintenance device.

8. The insertion apparatus in accordance with Claim 1, wherein said at least one maintenance device comprises at least one of the following: an optical sensor, a mechanical sensor, a thermal sensor, a magnetic sensor, an acoustic sensor, and an electromagnetic sensor.

Date Reçue/Date Received 2023-01-27

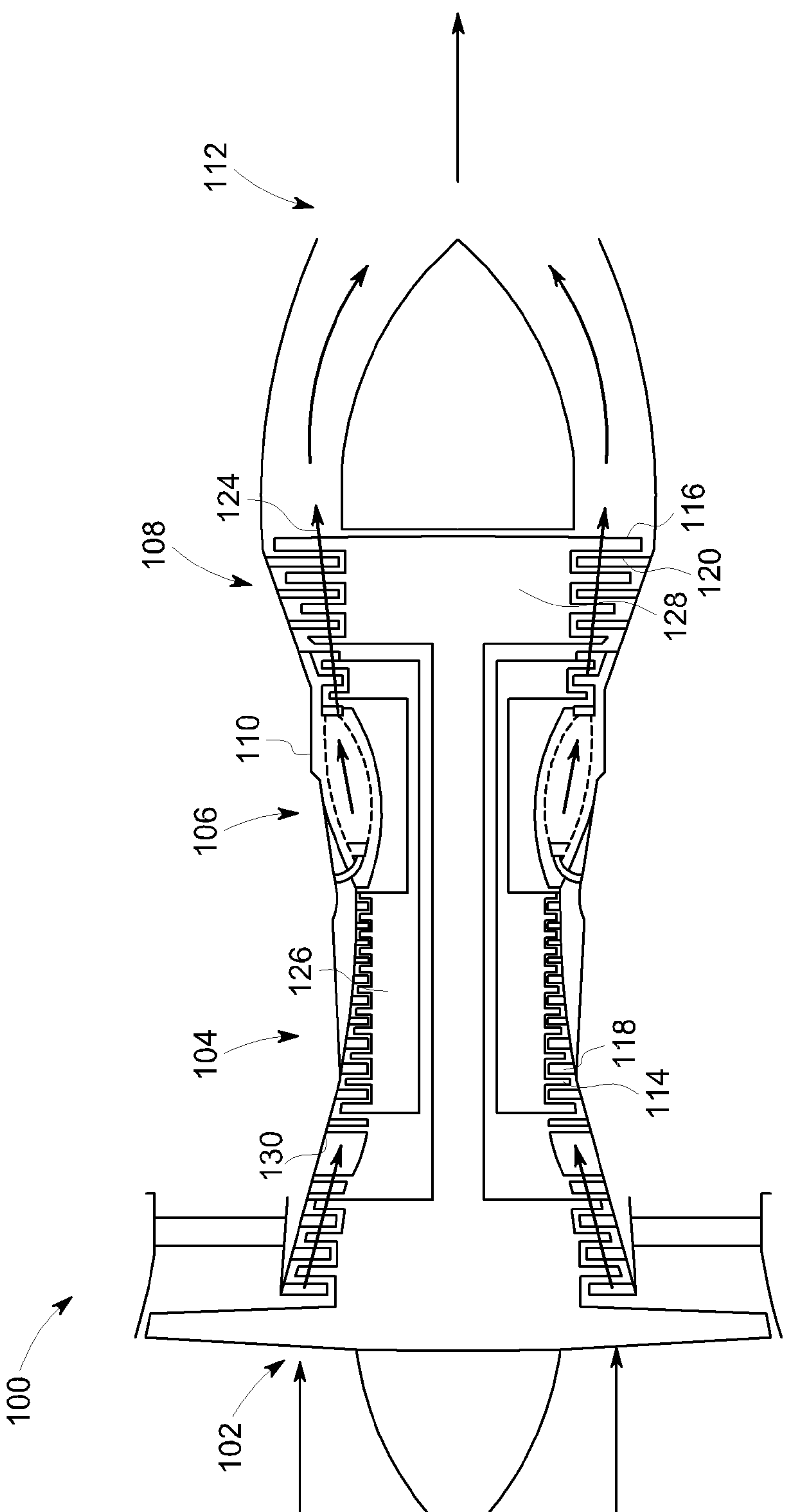


FIG. 1

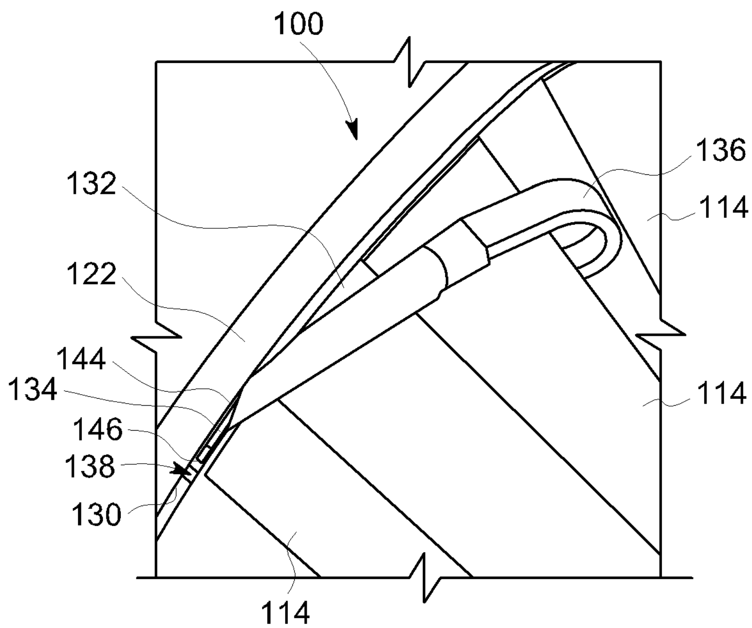


FIG. 2

Date Reçue/Date Received 2020-09-29

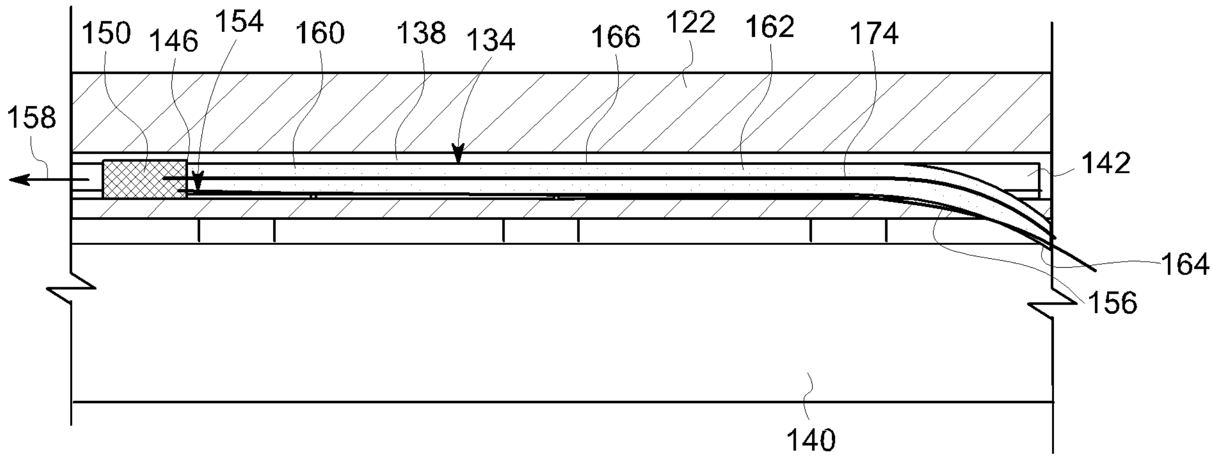


FIG. 3

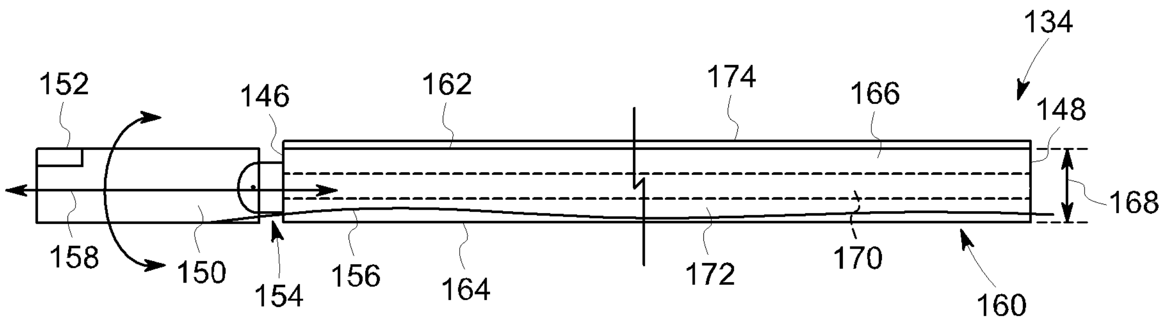


FIG. 4

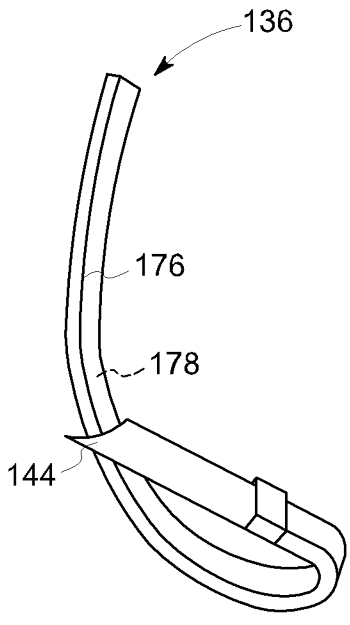


FIG. 5

Date Reçue/Date Received 2020-09-29

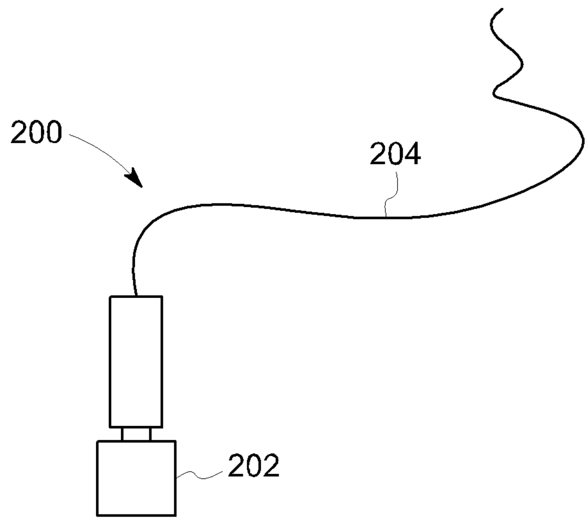


FIG. 6

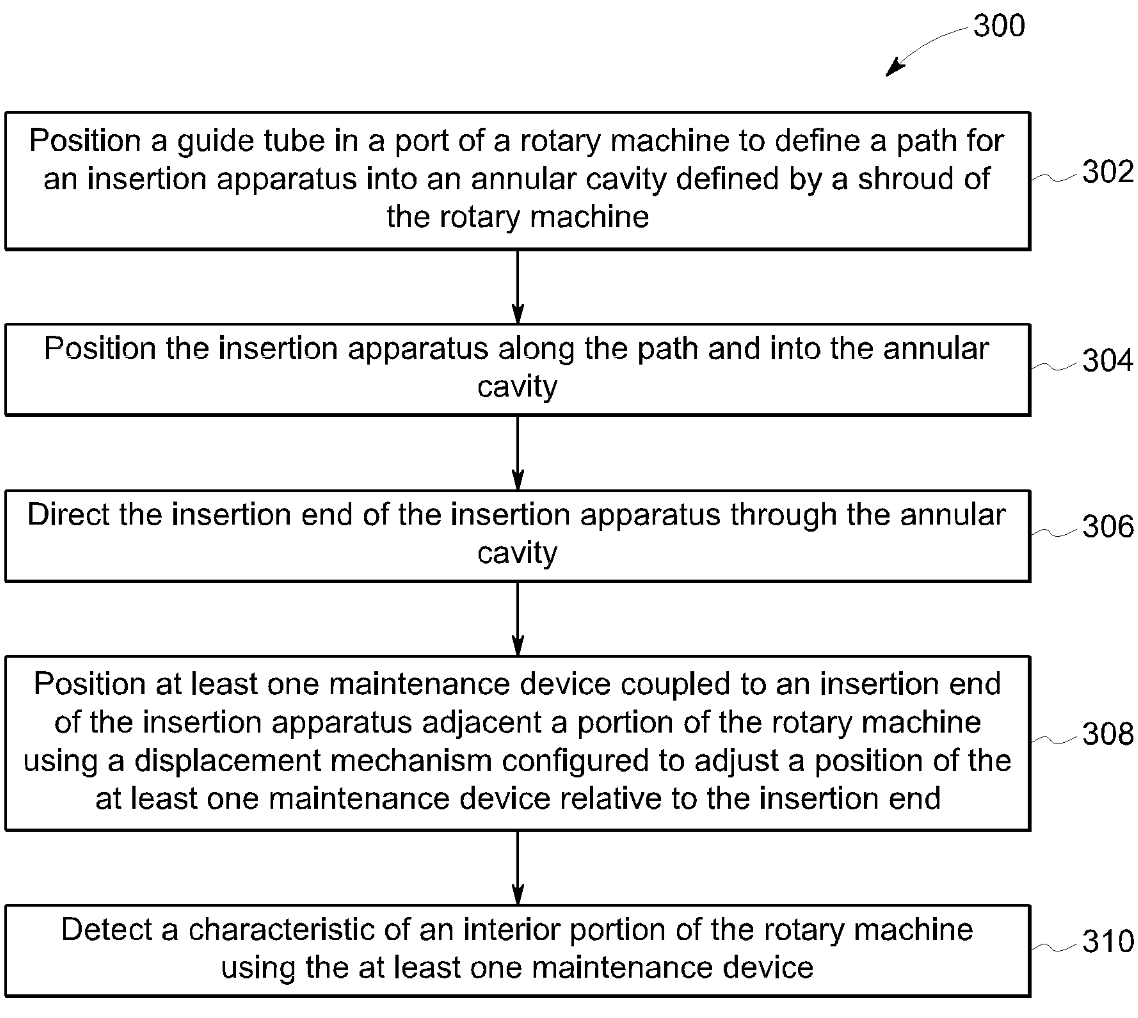
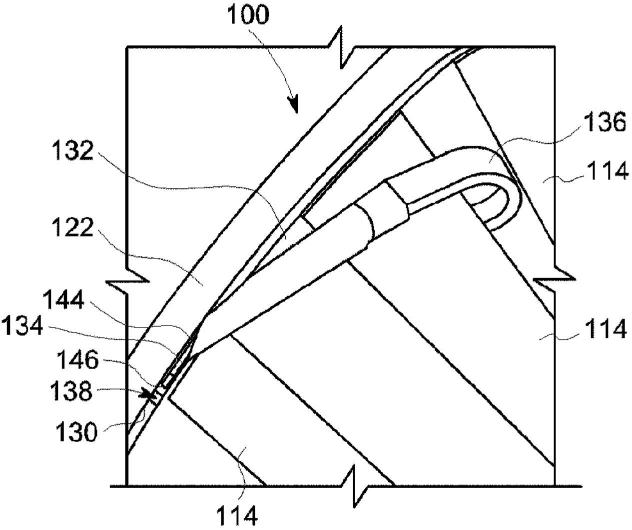


FIG. 7

Date Reçue/Date Received 2020-09-29



100
136
132
114
122
144
134
146
138
130
114
114